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1000 units of stellar distance, and it may be nearly ten times this amount. If we were to adopt the value of the absorption constant derived by Kapteyn, then the smallest color indices in the cluster should be in excess of 2.5 magnitudes, and that for a star of spectrum M should be nearly five magnitudes. Actually not a single color index greater than two magnitudes has been observed. If we were to take Van Rhijn's value, the color indices in the cluster would all need to exceed a magnitude.

It seems to be necessary to conclude that the selective extinction of light in space is entirely inappreciable, at least in the direction of the Hercules cluster. If we grant, on the basis of our data, a color excess of a tenth of a magnitude, and attribute it all to space absorption, the value of the coefficient can not then exceed +0.0001 mag., an amount completely negligible in dealing with the ordinary isolated stars. In the light of this result we are probably justified in assuming that the non-selective absorption in space (obstruction) is also negligible.

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STUDIES OF MAGNITUDES IN STAR CLUSTERS, II. ON THE SEQUENCE OF SPECTRAL TYPES IN STELLAR EVOLUTION

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In many investigations of globular clusters the apparent magnitudes of the individual stars, which are the quantities observed directly, may be used without error as representing the absolute magnitudes. We may consider the stars in such a system to be at the same distance from the earth, and knowledge of that distance is unnecessary in discussing the relations between changes in the absolute luminosities of the stars and their colors or spectra.

If, as is most commonly believed, the evolution of the stars progresses, chiefly through the agency of condensation and cooling, from the bluer spectral types to the redder, then, since it is definitely known that the intrinsic surface brightness of the blue stars greatly exceeds that of the red, we should normally expect to find that all the bright stars in the clusters are relatively blue and that the colors *g* and *k* do not appear until we go several magnitudes fainter than the brightest stars. This condition of increasing redness with decreasing brightness holds with but few exceptions among the stars in the open and moving clusters, such as the systems of the Pleiades, the Hyades, Ursa Major, and Messier 67. In the great globular cluster in Hercules (Messier 13), however, the interval of the four brightest magnitudes contains red and blue stars in approximately equal numbers.

In the following table the average magnitudes in Messier 13 are given for successive concentric regions and for different classes of color. The progression from blue to red is from left to right. As in the preceding paper of this series the data for the stars of the innermost regions of the cluster are not included, though the results would not be affected materially by retaining them. Each magnitude represents the mean value for about 16 stars.

It should be remembered that the system of Messier 13 is immensely remote from the sun and is enormous in its real dimensions, and also that it contains in all probability hundreds of thousands of stars. The longest exposures at Mount Wilson indicate that there are about 50,000 stars in the cluster brighter than magnitude 21, and there is no indication that the fainter limit has been approached. The same conclusions are valid for other condensed globular clusters. Hence, we must recognize that in studying stars between magnitudes 12 and 16 in Messier 13 we are dealing only with those members of the system that have the greatest intrinsic luminosity. Obviously, then, the giant red and yellow stars, which in Russell's hypothesis of the order of stellar evolution play an important part as the antecedents of the bluer stars, are present in great numbers in Messier 13.

TABLE I

AVERAGE MAGNITUDES IN MESSIER 13

LIMITS OF DISTANCE FROM CENTER	COLOR CLASS					ALL COLORS
	b	a	f	g	k	
2′.0 to 2′.5	15.18	15.12	14.88	14.36	12.11	14.76
2 .5 3 .0	15.22	14.75	14.89	14.03	12.74	14.58
3 .0 4 .0	15.16	15.14	14.81	14.18	12.19	14.67
4 .0 5 .0	15.25	15.22	14.92	14.70	13.66	14.91
5 .0 6 .0	15.22	14.96	14.84	14.15		14.62
> 6 .0	15.16	14.03	14.74	14.54	13.69	14.67
Total............	15.20	15.01	14.85	14.28	12.74	14.71

Although in the relatively near moving clusters, referred to above, there are very few of the giant red stars, their very frequent occurrence among the stars of the general galactic system is commonly recognized. From different lines of evidence we believe them to be tolerably normal stellar objects as regards mass, motions, and surface luminosities, but differing from dwarf red stars most conspicuously in density, dimensions, and total brightness. Admitting this interpretation, there is no place at all for the giant stars in the older and more conventional scheme of stellar evolution, but they harmonize almost completely with the newer evolutionary hypothesis.

From the best data available two years ago, Russell concluded that the giant stars of all spectral types have very similar absolute magnitudes. We are now in a position to make a further contribution to this subject, basing our conclusions upon results from globular clusters. Although later researches may show that our immediate galactic domain is comparable with a globular cluster to a limited extent only, there can be, nevertheless, but little doubt that each globular cluster is in itself a complete system, distinct from the galaxy, and one in which the evolution of the constituent stars probably follows analogous lines to the stellar development in our own system. In many respects it should be possible to read the observed features of the cluster directly into our interpretations of the local system, and the characteristic discussed below is probably such a case.

Table I shows the common dependence of average magnitude upon color class in the different regions of the cluster. The relation is better exhibited in Table II, which gives the average color index for successively fainter intervals of magnitude in different regions. The number of stars included in each average is in parentheses.

TABLE II

AVERAGE COLOR INDICES IN MESSIER 13

MAGNITUDE INTERVAL	DISTANCE FROM CENTER OF CLUSTER			ALL REGIONS
	2′.0 to 3′.0	3′.0 to 5′.0	> 5′.0	
11.8 to 12.6	+1.25 (8)	+1.34 (5)	(0)	+1.28 (13)
12.6 13.2	+0.81 (14)	+0.97 (6)	+0.85 (4)	+0.86 (24)
13.2 13.8	+0.95 (11)	+0.97 (6)	+0.97 (6)	+0.96 (23)
13.8 14.4	+0.71 (27)	+0.72 (36)	+0.81 (13)	+0.73 (76)
14.4 15.0	+0.67 (48)	+0.62 (37)	+0.67 (25)	+0.65 (110)
15.0 15.6	+0.31 (90)	+0.46 (97)	+0.39 (35)	+0.39 (222)

The data of the two tables show conclusively that the brightest stars in the cluster are the red and yellow giants. In fact there are 16 *g*'s and *k*'s more luminous than the very brightest *b*, which is an exceptional star; and of the 221 brightest stars in these outer regions of the cluster there are only four in color class *b* and twenty in class *a*.

Fainter than the fifteenth magnitude the bluer colors become very common and there is an indication that the reddest stars may be almost entirely absent between magnitudes 15.5 and 17.0. At any rate, between magnitudes 16.0 and 16.8 only four stars out of the hundred measured have color indices greater than half a magnitude, and none is found redder than the sun. If the result is confirmed by later study it will be very important. It would suggest that this magnitude interval represents in the cluster the special domain in the luminosity sequence of the normal first type star, and that the dwarf stars of the redder spectral types (including bodies comparable to the sun) will be found among the still fainter members of the system.

From the foregoing considerations we conclude that not only are giant second type stars present in large numbers in the globular clusters, but also on the average among the four or five brightest magnitudes the brighter the star the redder its color. This condition is the inverse of that for the dwarfs, where, without much doubt, the cooling stars are growing redder, fainter, and smaller with age. In the conventional scheme of the evolutionary transition of spectral types the present result introduces serious difficulties; for Russell's hypothesis, however, the difficulties are not so severe, but still the immediate ancestry of these giant red stars must be taken into account. More detailed considerations of the observations and their interpretation will appear in a forthcoming *Contribution from the Mount Wilson Solar Observatory.*

The following references may be cited:

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